Abstract

Micron scale robots going inside our body and curing various ailments is a technological dream that easily captures our imagination. However, with the advent of novel nanofabrication and nanocharacterization tools there has been a surge in the research in this field over the last decade. In order to achieve locomotion (swim) at these small length scales, special strategies need to be adopted, that is able to overcome the large viscous damping that these microbots have to face while moving in the various bodily fluids. Thus researchers have looked into the swimming strategies found in nature like that of bacteria like *E.coli* found in our gut or *spermatozoa* in the reproductive mucus. Biomimetic swimmers that replicate the motion of these small microorganisms hold tremendous promise in a host of biomedical applications like targeted drug delivery, microsurgery, biochemical sensing and disease diagnosis.

In one such method of swimming at very low Reynolds numbers, a micron scale helix has been fabricated and rendered magnetic by putting a magnetic material on it. Small rotating magnetic fields could be used then to rotate the helix, which translated as a result of the intrinsic translation rotation coupling in a helix. The present work focussed on the development of such a system of nanopropellers, a few microns in length, the characterization of its dynamics and velocity fluctuations originating from thermal noise. The work has also showed a possible application of the nanopropellers in microrheology where it could be used as a new tool to measure the rheological characteristics of a complex heterogeneous environment with very high spatial and temporal resolutions.

A generalized study of the dynamics of these propellers under a rotating field, has showed the existence of a variety of different dynamical configurations. Rigid body

dynamics simulations have been carried out to understand the behaviour. Significant amount of insight has been gained by solving the equations of motion of the object analytically and it has helped to obtain a complete understanding, along with providing closed form expressions of the various characteristics frequencies and parameters that has defined the motion.

A study of the velocity fluctuations of these chiral nanopropellers has been carried out, where the nearby wall of the microfluidic cell was found to have a dominant effect on the fluctuations. The wall has been found to enhance the average level of fluctuations apart from bringing in significant non Gaussian effects. The experimentally obtained fluctuations has been corroborated by a simulation in which a time evolution study of the governing 3D Langevin dynamics equations has been done. A closer look at the various sources of velocity fluctuations and a causality study thereof has brought out a minimum length scale below which helical propulsion has become impractical to achieve because of the increased effect of the orientational fluctuations of the propeller at those small length scales.

An interesting bistable dynamics of the propeller has been observed under certain experimental conditions, in which the propeller randomly switched between the different dynamical states. This defied common sense because of the inherent deterministic nature of the governing Stokes equation. Rigid body dynamics simulations and stability analysis has shown the existence of time scales in which two different dynamical states of the propeller have become stable. Thus the intrinsic dynamics of the system has been found to be the reason behind the bistable behaviour, randomness being brought about by the thermal fluctuations present in the system.

Finally, in a novel application of the propellers, they have been demonstrated as a tool for microrheological mapping in a complex fluidic environment. The studies done in this work have helped to develop this method of active microrheology in which the measurement times are orders of magnitude smaller than its existing counterparts.